LOW PERMEABILITY AIRBAG CUSHIONS HAVING EXTREMELY LOW COATING LEVELS

Cross Reference to Related Applications

This application is a continuation-in-part of co-pending application 09/350,620, filed on July 7, 1999. This parent application is herein entirely incorporated by reference.

Field of the Invention

This invention relates generally to coated inflatable fabrics and more particularly concerns airbag cushions to which very low add-on amounts of coating have been applied and which exhibit extremely low air permeability. The inventive inflatable fabrics are primarily for use in automotive restraint cushions that require low permeability characteristics (such as side curtain airbags). Traditionally, heavy, and thus expensive, coatings of compounds such as neoprene, silicones and the like, have been utilized to provide such required low permeability. The inventive fabric utilizes an inexpensive, very thin coating to provide such necessarily low permeability levels. Thus, the inventive coated inflatable airbag possesses a coating comprising an elastomeric material (or materials) coated on the target fabric wherein the elastomeric material possesses a tensile strength of at least 2,000 and an elongation at break of at least 180%. The coating is then applied to the airbag surface in an amount of at most 2.5 ounces per square yard (and preferably forms a film). The inventive airbag exhibits a characteristic leak-down time (defined as the ratio of inflated bag volume to bag

volumetric leakage rate at 10 psi) of at least 5 seconds after inflation. The resultant airbag cushions, particularly low permeability cushions exhibiting very low rolled packing volumes, are intended to reside within the scope of this invention.

Background of the Prior Art

Airbags for motor vehicles are known and have been used for a substantial period of time. A typical construction material for airbags has been a polyester or nylon fabric, coated with an elastomer such as neoprene, or silicone. The fabric used in such bags is typically a woven fabric formed from synthetic yarn by weaving practices that are well known in the art.

The coated material has found acceptance because it acts as an impermeable barrier to the inflation medium. This inflation medium is generally nitrogen, helium, or other like gases generated from a gas generator or inflator. Such gas is conveyed into the cushion at a relatively warm temperature. The coating obstructs the permeation of the fabric by such hot gas, thereby permitting the cushion to rapidly inflate without undue decompression during a collision event.

Airbags may also be formed from uncoated fabric which has been woven in a manner that creates a product possessing low permeability or from fabric that has undergone treatment such as calendaring to reduce permeability. Fabrics which reduce air permeability by calendaring or other mechanical treatments after weaving are disclosed in U.S. Patent 4,921,735; U.S. Patent 4,977,016; and U.S. Patent 5,073,418 (all incorporated herein by reference).

Silicone coatings typically utilize either solvent based or complex two

component reaction systems. Silicone coating weight for a traditional driver side air bag is usually 0.5 – 1.2 oz/yd^2. Very different from driver and passenger side air bags, side curtain bags, which emerged in the in late 1990's, are intended to protect occupants during side impact and roll over collisions. A side curtain bag usually has higher working pressure and more importantly, has to to stay inflated within a specific pressure range for a duration of time at least two orders of magnitude longer than the duration of inflation for a driver side or passenger side airbags. Dry coating weights for silicone have been in the range of about 3 to 4 ounces per square yard or greater for both the front and back panels of side curtain airbags. Lower coating weight for the side curtain bags has not been achieved without sacrificing performance. As will be appreciated by one of ordinary skill in this art, high add on weights substantially increase the cost of the base fabric for the airbag and make packing within small airbag modules very difficult. Furthermore, silicone exhibits very low tensile strength and low tear resistance characteristics which do not withstand high pressure inflation easily without the utilization of very thick coatings.

The use of certain polyurethanes as coatings as disclosed in U.S. Patent 5,110,666 to Menzel et al. (herein incorporated by reference) permits low add on weights reported to be in the range of 0.1 to 1 ounces per square yard but the material itself is relatively expensive and is believed to require relatively complex compounding and application procedures due to the nature of the coating materials. Patentees, however, fails to disclose any pertinent elasticity and/or tensile strength characteristics of their particular polyurethane coating materials. Furthermore, there is no discussion pertaining to the importance of the coating ability (and thus correlated low air

permeability or characteristic leak-down time) at low add-on weights of such polyurethane materials on the new side curtain airbags either only for fabrics which are utilized within driver or passenger side cushions. All airbags must be inflatable extremely quickly; upon sensing a collision, in fact, airbags usually reach peak pressures within 10 to 20 milliseconds. Regular driver side and passenger side air bags are designed to withstand this enormous inflation pressure; however, they also deflate very quickly in order to effectively absorb the energy from the vehicle occupant hitting the bag. Such driver and passenger side cushions (airbags) are thus made from low permeability fabric, but they also deflate quickly at connecting seams and through vent holes. Furthermore, the low add-on coatings taught within Menzel, and within U.S. Patent 5,945,186 to Li et al., would not provide long-term gas retention; they would actually not withstand the prolonged and continuous pressures supplied by activated inflators for more than about 2 seconds, at the most. The low permeability of these airbag fabrics thus aid in providing a small degree of sustained gas retention within driver and passenger airbag cushions to provide the deflating cushioning effects necessary for sufficient collision protection. Such airbag fabrics would not function well with side curtain airbags, since, at the very least, the connecting seams which create the pillowed, cushioned structures within such airbags, as discussed in greater detail below, would not be coated. As these areas provide the greatest degree of leakage during and after inflation, the aforementioned patented low coating low permeability airbag fabrics would not be properly utilized within side curtain airbags.

As alluded to above, there are three primary types of different airbags, each for different end uses. For example, driver-side airbags are generally mounted within

steering columns and exhibit relatively high air permeabilities in order to act more as a cushion for the driver upon impact. Passenger-side airbags also comprise relatively high air permeability fabrics which permit release of gas either therethrough or through vents integrated therein. Both of these types of airbags are designed to protect persons in sudden collisions and generally burst out of packing modules from either a steering column or dashboard (and thus have multiple "sides"). Side curtain airbags, however, have been designed primarily to protect passengers during rollover crashes by retaining its inflation state for a long duration and generally unroll from packing containers stored within the roofline along the side windows of an automobile (and thus have a back and front side only). Side curtain airbags therefore not only provide cushioning effects but also provide protection from broken glass and other debris. As such, it is imperative that side curtain airbags, as noted above, retain large amounts of gas, as well as high gas pressures, to remain inflated throughout the longer time periods of the entire potential rollover situation. To accomplish this, these side curtains are generally coated with very large amounts of sealing materials on both the front and back sides. Since most side curtain airbag fabrics comprise woven blanks that are either sewn, sealed, or integrally woven together, discrete areas of potentially high leakage of gas are prevalent, particularly at and around the seams. It has been accepted as a requirement that heavy coatings were necessary to provide the low permeability (and thus high leak-down time) necessary for side curtain airbags. Without such heavy coatings, such airbags would most likely deflate too quickly and thus would not function properly during a rollover collision. As will be well understood by one of ordinary skill in this art, such heavy coatings add great cost to the overall manufacture of the target side

curtain airbags. There is thus a great need to manufacture low permeability side curtain airbags with less expensive (preferably lower coating add-on weight) coatings without losing the heat aging, humidity aging, and permeability characteristics necessary for proper functioning upon deployment. To date, there has been little accomplished, if anything at all, alleviating the need for such thick and heavy airbag coatings from side curtain airbags.

Furthermore, there is a current drive to store such low permeability side curtain airbags within cylindrically shaped modules. Since these airbags are generally stored within the rooflines of automobiles, and the area available is quite limited, there is always a great need to restrict the packing volume of such restraint cushions to their absolute minimum. However, the previously practiced low permeability side curtain airbags have proven to be very cumbersome to store in such cylindrically shaped containers at the target automobile's roofline. The actual time and energy required to roll such heavily coated low permeability articles as well as the packing volume itself, has been very difficult to reduce. Furthermore, with such heavy coatings utilized, the problems of blocking (i.e., adhering together of the different coated portions of the cushion) are amplified when such articles are so closely packed together. The chances of delayed unrolling during inflation are raised when the potential for blocking is present. Thus, a very closely packed, low packing volume, low blocking side curtain low permeability airbag is highly desirable. Unfortunately, the prior art has again not accorded such an advancement to the airbag industry.

Objects and Brief Description of the Invention

In light of the background above, it can be readily seen that there exists a need for a low permeability, side curtain airbag that utilizes lower, and thus less expensive, amounts of coating, and therefore exhibits a substantially reduced packing volume over the standard low permeability type side curtain airbags. Such a coated low permeability airbag must provide a necessarily high leak-down time upon inflation and after long-term storage. Such a novel airbag and a novel coating formulation provides marked improvements over the more expensive, much higher add-on airbag coatings (and resultant airbag articles) utilized in the past.

It is therefore an object of this invention to provide a coated airbag, wherein the coating is present in a very low add-on weight, possessing extremely high leak-down time characteristics after inflation and thus complementary low permeability characteristics. Another object of the invention is to provide an inexpensive side curtain airbag cushion. A further object of this invention is to provide an highly effective airbag coating formulation which may be applied in very low add-on amounts to obtain extremely low permeability airbag structures after inflation. An additional object of this invention is to provide an airbag coating formulation which not only provides beneficial and long-term low permeability, but also exhibits excellent long-term storage stability (through heat aging and humidity aging testing). Yet another object of the invention is to provide a low permeability side curtain airbag possessing a very low rolled packing volume and non-blocking characteristics for effective long-term storage within the roofline of an automobile.

Accordingly, this invention is directed to an airbag cushion comprising a coated

fabric, wherein said fabric is coated with an elastomeric composition in an amount of at most 2.5 ounces per square yard of the fabric; and wherein said airbag cushion, after long-term storage, exhibits a characteristic leak-down time of at least 5 seconds. Also, this invention concerns an airbag cushion comprising a coated fabric, wherein said fabric is coated with an elastomeric composition; wherein said elastomeric composition comprises at least one elastomer possessing a tensile strength of at least 1,500 psi and an elongation of at least 180%; and wherein said airbag cushion, after long-term storage, exhibits a characteristics leak-down time of at least 5 seconds. Additionally, this invention encompasses a coated airbag cushion which exhibits a rolled packing volume factor (measured as unrolled fabric length the rolled diameter of the airbag cushion)of at least 17.

The term "characteristic leak-down time" is intended to encompass the measurement of the pressure decay characteristic of a side curtain bag after the bag is inflated to the peak working pressure. The pressure decay curve of a side curtain airbag most resembles a mathematical exponential decay curve wherein a simple time constant is utilize to characterize the entire curve. The characteristic leak-down time used in this invention serves as the time constant in describing the pressure decay of air bag. The measurement is made on an already-inflated (to a peak initial pressure which "opens" up the areas of weak sealing) and deflated airbag cushion upon subsequent re-inflation at a constant pressure at 10 psi. It is well known and well understood within the airbag art, and particularly concerning side curtain (low permeability) airbag cushions, that retention of inflation gas for long periods of time is of utmost importance during a collision. Side curtain airbags are designed to inflate as quickly as driver- and

passenger-side bags, but they must deflate very slowly to protect the occupants during roll over and side impact. Thus, it is imperative that the bag exhibits a very low leakage rate after the bag experiences peak pressure during the instantaneous, quick inflation. Hence, the coating on the bag must be strong enough to withstand the shock and stresses when the bag is inflated so quickly. Thus, a high characteristic leak-down time measurement is paramount in order to retain the maximum amount of beneficial cushioning gas within the inflated airbag. Airbag leakage after inflation (and after peak pressure is reached) is therefore closely related to actual pressure retention characteristics. The pressure retention characteristics (hereinafter referred to as "leak-down time") of already-inflated and deflated side curtain airbags can be described by a characteristic leak-down time t, wherein:

$$t \text{ (seconds)} = \frac{\text{Bag volume}(ft^3)}{\text{Volumetric leakage rate(SCFH*) at 10 Psi}} \times 3600$$

*SCFH: standard cubic feet per hour.

It is understood that the 10 psi constant is not a limitation to the invention; but merely the constant pressure at which the leak-down time measurements are made. Thus, even if the pressure is above or below this amount during actual inflation or after initial pressurizing of the airbag, the only limitation is that if one of ordinary skill in the art were to measure the bag volume and divide that by the volumetric leakage rate (measured by the amount leaking out of the target airbag during steady state inflation at 10 psi), the resultant measurement in time would be at least 5 seconds. Preferably, this time is greater than about 9 seconds; more preferably, greater than about 15 seconds;

and most preferably, greater than about 20 seconds.

Alternatively, and in a manner of measurement with uninflated side curtain airbags, the term "leak-down time" may be measured as the amount of time required for at half of the introduced inflation gas to escape from the target airbag after initial peak pressure is reached. Thus, this measurement begins the instant after peak initial pressure is reached upon inflation (such as, traditionally, about 30 psi) with a standard inflation module. It is well understood that the pressure of gas forced into the airbag after peak initial pressure is reached will not remain stable (it decreases during the subsequent introduction of inflation gas), and that the target airbag will inevitably permit escape of a certain amount of inflation gas during that time. The primary focus of such side curtain airbags (as noted above) is to remain inflated for as long as possible in order to provide sufficient cushioning protection to vehicle occupants during rollover accidents. The greater amount of gas retained, the better cushioning effects are provided the passengers. Thus, the longer the airbag retains a large amount of inflation gas, and consequently the greater the characteristic leak-down time, the better cushioning results are achieved. At the very least, the inventive airbag must retain at least 25%, preferably 50% or higher, of its inflated gas volume 5 seconds subsequent to reaching peak initial pressure. Preferably, this time is 9 seconds, more preferably 15 seconds, and most preferably 20 seconds.

Likewise, the term, "after long-term storage" encompasses either the actual storage of an inventive airbag cushion within an inflator assembly (module) within an automobile, besides in a storage facility awaiting installation. Such a measurement is generally accepted, and is well understood and appreciated by the ordinarily skilled

artisan, to be made through comparable analysis after representative heat and humidity aging tests (ASTM D 5427). These tests, adopted by the industry, generally involve 107° C oven aging for 16 days, followed by 83° C and 95% relative humidity aging for 16 days and are generally accepted as proper estimations of the conditions of long-term storage stability for airbag cushions. Thus, this term encompasses such measurement tests. The inventive airbag fabrics must exhibit proper characteristic leak-down times after undergoing such rigorous pseudo-storage testing.

Detailed Description of the Invention

The inventive elastomeric coating composition must comprise at least one elastomer that possesses a tensile strength of at least 1,500 psi and an elongation to break of greater than about 180%. Preferably, the tensile strength is at least 3,000 psi, more preferably, 4,000, and most preferably at least about 5,000. The high end is actually the highest one can produce which can still adhere to a fabric surface. The preferred elongation to break is more than about 200%, more preferably more than about 300%. These characteristics of the elastomer translate to a coating that is both very strong (and thus will withstand enormous pressures both at inflation and during the time after inflation and will not easily break) and can stretch to compensate for such large inflation, etc., pressures. Thus, when applied at the seams of a side curtain airbag, as well as over the rest of the airbag structure, the coating will most preferably (though not necessarily) form a continuous film. This coating acts to both fill the individual holes between the woven yarns and/or stitches, etc., as well as to "cement" the individual yarns in place. During inflation, then, the coating prevents leakage through

the interstitial spaces between the yarns and aids in preventing yarn shifting (which may create larger spaces for possible gas escape).

The utilization of such high tensile strength and high elongation at break components permits the consequent utilization, surprisingly, of extremely low add-on weight amounts of such coating formulations. Normally, the required coatings on side curtain airbags are very high, at least 3.0 ounces per square yard on each side of the bag (with the standard actually much higher than that, at about 4.0). The inventive airbag cushions require merely at most 2.5 oz/yd^2 on each side (preferably less, such as 2.0, more preferably 1.8, still more preferably, about 1.5, and most preferably, as low as 0.8) ounces per square yard of this inventive coating to effectuate the desired high leak-down time (low permeability). Furthermore, the past coatings were required to exhibit excellent heat and humidity aging stability. Unexpectedly, even at such low add-on amounts, and particularly with historically questionable coating materials (polyurethanes, for example), the inventive coatings, and consequently, the inventive coated airbag cushions, exhibit excellent heat aging and humidity aging characteristics. Thus, the coating compositions and coated airbags are clearly improvements within this specific airbag art.

Of particular interest as the elastomer components within the inventive elastomeric compositions are, specifically, polyamides, polyurethanes, acrylic elastomers, hydrogenated nitrile rubbers (i.e., hydrogenated NBR), butyl rubbers, EPDM rubbers, fluoroelastomers (i.e., fluoropolymers and copolymers containing fluoro-monomers), ethylene-vinylacetate copolymers, and ethylene acrylate copolymers. Also, such elastomers may or may not be cross-linked on the airbag

surface. Preferably, the elastomer is a polyurethane and most preferably is a polycarbonate polyurethane elastomer. Such a compound is available from Bayer Corporation under the tradename Impranil®, including Impranil® 85 UD, ELH, and EHC-01. Other acceptable polyurethanes include Bayhydrol® 123, also from Bayer; Ru 41-710, EX 51-550, and Ru 40-350, both from Stahl USA. Any polyurethane, or elastomer, for that matter, which exhibits the same tensile strength and elongation at break characteristics as noted above, however, are potentially available within the inventive coating formulation and thus on the inventive coated airbag cushion. In order to provide the desired leak-down times at long-term storage, however, the add-on weights of other available elastomers may be greater than others. However, the upper limit of 2.5 ounces per square yard should not be exceeded to meet this invention. The desired elastomers may be added in multiple layers if desired as long the required thickness for the overall coating is not exceeded. Alternatively, the mulitple layer coating system may also be utilized as long as at least one elastomer possessing the desired tensile strength and elongation at break is utilized.

Other possible components present within the elastomer coating composition are thickeners, antioxidants, antiblocking agents, crosslinking agents, surfactants, flame retardants, coalescent agents, adhesion promoters, and colorants. In accordance with the potentially preferred practices of the present invention, a dispersion (either solvent- or water-borne, depending on the selected elastomer) of finely divided elastomeric resin or a resin solution is compounded with a flame retardant to yield a compounded mix having a viscosity of about 8000 centipoise or greater. A polyurethane is potentially preferred, with a polycarbonate polyurethane, such as those noted above from Bayer

and Stahl, most preferred. Other potential elastomeric resins include other polyurethanes, such as Witcobond™ 253 (35% solids), from Witco, and Sancure, from BFGoodrich, Cleveland, Ohio; hydrogenated NBR, such as Chemisat™ LCH-7335X (40% solids), from Goodyear Chemical, Akron, Ohio; EPDM, such as EP-603A rubber latex, from Lord Corporation, Erie, Pennsylvania; butyl rubber, such as Butyl rubber latex BL-100, from Lord Corporation; and acrylic rubber (elastomers), such as HyCar™, from BFGoodrich. This list should not be understood as being all-inclusive, only exemplary of potential elastomers. Furthermore, the preferred elastomer will not include any silicone, due to the extremely low tensile strength (typically below about 1,500 psi) characteristics exhibited by such materials. However, in order to provide effective aging and non-blocking benefits, such components may be applied to the elastomeric composition as a topcoat as long as the add-on weight of the entire elastomer and topcoat does not exceed 2.5 ounces per square yard. Additionally, elastomers comprising certain polyester or polyether segments (such as polypropylene oxide) or other similar components, are undesirable, particularly at very low add-on weights (i.e., 0.8-1.2 oz/yd^2) due to stability problems in heat and humidity aging (polyesters easily hydrolyze in humidity and polyethers easily oxidize in heat); however, such elastomers may be utilized in higher add-on amounts as long, again, as the 2.5 ounces per square yard on each side is not exceeded.

Among the other additives particularly preferred within this elastomer composition are heat stabilizers, flame retardants, primer adhesives, antiblocking agents and materials for protective topcoats. A potentially preferred thickener is marketed under the trade designation NATROSOL™ 250 HHXR by the Aqualon division of

Hercules Corporation which is believed to have a place of business at Wilmington, Delaware. In order to meet Federal Motor Vehicle Safety Standard 302 flame retardant requirements for the automotive industry, a flame retardant is also preferably added to the compounded mix. One potentially preferred flame retardant is AMSPERSE F/R 51 marketed by Amspec Chemical Corporation which is believed to have a place of business at Gloucester City New Jersey. Primer adhesives may be utilized to facilitate adhesion between the surface of the target fabric and the elastomer itself. Thus, although it is preferable for the elastomer to be the sole component of the entire elastomer composition in contact with the fabric surface, it is possible to utilize adhesion promoters, such as isocyanates, epoxies, functional silanes, and other such resins with adhesive properties, without deleteriously effecting the ability of the elastomer to provide the desired low permeability for the target airbag cushion. An adhesive primer coating may be applied directly to the fabric before applying the inventive high strength elastomeric coating to assure great adhesion strength.

A topcoat component, as with potential silicones, as noted above, may also be utilized to effectuate proper non-blocking characteristics to the target airbag cushion. Most elastomers, including certain grades of silicones or polyurethanes, suitable for sealing the side curtain structures exhibit high surface frictions and tend to block at elevated temperature. High surface friction would slow down airbag deployment (unfolding/unrolling) and compromise the safety provided by the airbag. The current side curtain airbag uses a nonwoven fabric on top of the silicone coating to provide the necessary low friction in addition to providing nonblocking benefits. But the nonwoven fabric significantly increases the packing volume and the total cost. It has

now been found that by using an elastomer with significantly higher hardness and higher softening point as topcoat, a non-blocking and low friction surface can be achieved with lower cost and improved packing volume. The higher hardness and higher softening point can also be achieved by using crosslinking agents in the topcoat. Suitable crosslinking agents are, without limitation, melamine-formaldehyde resin, polyisocyanates (difunctional, trifunctional and polyfunctional), epoxy crosslinking resins, polyaziridines, carbodiimide crosslinking resins, phenol formaldehyde resin, urea formaldehyde resin and the like. A sliding coefficient of friction of less than about 0.7 (measured according to ASTM D 4518 test method B) can be achieved by using topcoats possessing significantly higher hardness and softening point properties. Such a topcoat may also perform various other functions, including, but not limited to, improving aging of the elastomer coating (such as with silicone) or providing further reinforcement to the elastomer coating materials (most noticeably with the preferred polycarbonate polyurethanes). The topcoat materials thus can be selected from, besides silicones, a group of organic polymer resins that have higher softening point and hardness upon coating and possible curing. Examples of those materials are, polyurethanes, polyacrylates, epoxy resins, ethylene-vinyl acetate copolymers, fluoropolymers, polyamides, and polyesters.

Airbag fabrics must pass certain tests in order to be utilized within restraint systems. One such test is called a blocking test which indicates the force required to separate two portions of coated fabric from one another after prolonged storage in contact with each other (such as an airbag is stored). Laboratory analysis for blocking entails pressing together coated sides of two 2 inch by 2 inch swatches of airbag fabric

at 5 psi at 100°C for 7 days. If the force required to pull the two swatches apart after this time is greater than 50 grams, or the time required to separate the fabrics utilizing a 50 gram weight suspended from the bottom fabric layer is greater than 10 seconds, the coating fails the blocking test. Clearly, the lower the required separating shear force, the more favorable the coating. For improved blocking resistance (and thus the reduced chance of improper adhesion between the packed fabric portions), topcoat components may be utilized, such as talc, silica, silicate clays, starch powders and topcoat polymer resins mentioned earlier, as long as the add-on weight of the entire elastomer composition (including the topcoat) does not exceed 2.5 ounces per square yard (and preferably exists at a much lower level, about 1.5, for instance).

Two other tests which the specific coated airbag cushion must pass are the oven (heat) aging and humidity aging tests. Such tests also simulate the storage of an airbag fabric over a long period of time upon exposure at high temperatures and at relatively high humidities. These tests are actually used to analyze alterations of various different fabric properties after such a prolonged storage in a hot ventilated oven (>100°C) (with or without humid conditions) for 2 or more weeks. For the purposes of this invention, this test was used basically to analyze the air permeability of the coated side curtain airbag by measuring the characteristic leak-down time (as discussed above, in detail). The initially produced and aged inventive airbag cushion should exhibit a characteristic leak-down time of greater than about 5 seconds (upon re-inflation at 10 psi gas pressure after the bag had previously been inflated to a peak pressure above about 15 psi and allowed to fully deflate) under such harsh aging conditions. Since polyurethanes, the preferred elastomers in this invention, may be deleteriously affected by high heat and

humidity (though not as deleteriously as certain polyester and polyether-containing elastomers), it may be prudent to add certain components within a topcoat layer and/or within the elastomer itself. Antioxidants, antidegradants, and metal deactivators may be utilized for this purpose. Examples include, and are not intended to be limited to, Irganox® 1010 and Irganox® 565, both available from CIBA Specialty Chemicals. This topcoat may also provide additional protection against aging and thus may include topcoat aging improvement materials, such as, and not limited to, polyamides, NBR rubbers, EPDM rubbers, polyurethanes, melamine-formaldehyde resin, urea formaldehyde resin, polyacrylate, silicones, polyacrylates, fluoropolymers and the like, as long as the elastomer composition (including the topcoat) does not exceed the 2.5 ounces per square yard (preferably much less than that, about 1.5 at the most) of the add-on weight to the target fabric.

Other additives may be present within the elastomer composition, including, and not limited to, colorants, UV stabilizers, fillers, pigments, and crosslinking/curing agents, as are well known within this art.

It is further noted that silicones may be applied on certain airbags within this invention as long as the construction of the airbag permits long characteristic leak-down times with such silicones.

Scrape coating methods are typically utilized to apply standard silicone coatings on regular air bag fabrics (driver and passenger side air bags). Since the scrape-coating knife remains in constant contact with the high points of the yarns on the target fabric, the resultant coating exhibits large thickness variations on the fabric surface or forms a discontinous film. The thin points in the resultant coating then become the weak point

for potential failure during inflation and contribute to high leakage rate.

However, due to the unevenness of the fabric surface topology, a coating method that allows for production of a relatively uniform continuous film on the target fabric surface with good adhesion is most preferred. Fixed gap coating procedures provide the best results. Such coating procedures include knife-over-roll, roll-over-roll, and the like. Transfer roll coating methods (such as reverse roll, calender roll ,and gravure roll) may also be used since it can provide a continuous and uniform coating on the fabric. Extrusion coating and slot die coating methods are also possible as long as they provide good adhesion. Resin solutions or dispersions are preferred in fixed gap coating process. For the same dry coating weight, significantly larger gap resetting is used for resin solutions or dispersions than for 100% resin systems. A higher gap setting allows for the production of a film exhibiting a more uniform coating thickness. Most preferred is the utilization of a resin solution since it provides a better film formation process (a resin dispersion requires complete resin particle coalescence to form a good film).

The substrate to which the inventive elastomeric coatings are applied to form the airbag base fabric in accordance with the present invention is preferably a woven fabric formed from yarns comprising synthetic fibers, such as polyamides or polyesters. Such yarn preferably has a linear density of about 105 denier to about 840 denier, more preferably from about 210 to about 630 denier. Such yarns are preferably formed from multiple filaments wherein the filaments have linear densities of about 6 denier per filaments or less and most preferably about 4 denier per filament or less. In the more preferred embodiment such substrate fabric will be formed from fibers of nylon, and

most preferred is nylon 6,6. It has been found that such polyamide materials exhibit particularly good adhesion and maintenance of resistance to hydrolysis when used in combination with the coating according to the present invention. Such substrate fabrics are preferably woven using fluid jet weaving machines as disclosed in U.S. Patents 5,503,197 and 5,421,378 to Bower et al. (incorporated herein by reference). Such woven fabric will be hereinafter referred to as an airbag base fabric. As noted above, the inventive airbag must exhibit extremely low permeability and thus must be what is termed a "side curtain" airbag. As noted previously and extensively, such side curtain airbags (a.k.a., cushions) must retain a large amount of inflation gas during a collision in order to accord proper long-duration cushioning protection to passengers during rollover accidents. Any standard side curtain airbag may be utilized in combination with the low add-on coating to provide a product which exhibits the desired leak-down times as noted above. Some side curtain airbags are produced through labor-intensive sewing or stitching (or other manner) together two separate woven fabric blanks to form an inflatable structure. Furthermore, as is well understood by the ordinarily skilled artisan, such sewing, etc., is performed in strategic locations to form seams (connection points between fabric layers) which in turn produce discrete open areas into which inflation gasses may flow during inflation. Such open areas thus produce pillowed structures within the final inflated airbag cushion to provide more surface area during a collision, as well as provide strength to the bag itself in order to withstand the very high initial inflation pressures (and thus not explode during such an inflation event). For sewn side curtain airbags, this inventive coating, applied on the flat fabric and sewn seams, provides excellent comb-out resistance at the sewn seam and provides

low air leakage throughout both the seam and the fabric. Other side curtain airbag cushions exist which are of the one-piece woven variety. Basically, some inflatable airbags are produced through the simultaneous weaving of two separate layers of fabric which are joined together at certain strategic locations (again, to form the desired pillowed structures). Such cushions thus present seams of connection between the two layers. It is the presence of so many seams (in both multiple-piece and one-piece woven bags) which create the aforementioned problems of gas loss during and after inflation. The possibility of yarn shifting, particularly where the yarns shift in and at many different ways and amounts, thus creates the quick deflation of the bag through quick escaping of inflation gasses. Thus, the base airbag fabrics do not provide much help in reducing permeability (and correlated leak-down times, particularly at relatively high pressures). It is this seam problem which has primarily created the need for the utilization of very thick, and thus expensive, coatings to provide necessarily low permeability in the past.

Recently, a move has been made away from both the multiple-piece side curtain airbags (which require great amounts of labor-intensive sewing to attached woven fabric blanks) and the traditionally produced one-piece woven cushions, to more specific one-piece woven fabrics which exhibit substantially reduced floats between woven yarns to substantially reduce the unbalanced shifting of yarns upon inflation, such as in Ser. No. 09/406,264, to Sollars, Jr., the specification of which is completely incorporated herein. These one-piece woven bags are generally produced on dobby or jacquard fluid-jet looms, preferably the utilized one-piece airbag is made from a jacquard weaving process. With such an improvement, the possibility of high leakage

at seams is substantially reduced. These airbags provide balanced weave constructions at and around attachment points between two layers of fabrics such that the ability of the yarns to become displaced upon inflation at high pressures is reduced as compared with the traditional one-piece woven airbags. Due its greatly improved virtually float free and balanced seam structure, such one-piece woven structures permit extremely low add-on amounts of elastomeric coatings for low permeability effects. In fact, these inventive airbags function extremely well with low add-on coatings below 1.5 and as low as about 0.5 ounces per square yard.

Furthermore, although it is not preferred in this invention, it has been found that the inventive coating composition provides similar low permeability benefits to standard one-piece woven airbags, particularly with the inventive low add-on amounts of high tensile strength, high elongation, non-silicone coatings; however, the amount of coating required to permit high leak-down times is much higher than for the aforementioned Sollars, Jr. inventive one-piece woven structure. Thus, add-on amounts of as much as 1.2 and even up to about 2.2 ounces per square yard may be necessary to effectuate the proper low level of air permeability for these other one-piece woven airbags. Even with such higher add-on coatings, the inventive coatings themselves clearly provide a marked improvement over the standard, commercial, prior art silicone, etc., coatings (which must be present in amounts of at least 3.0 ounces per square yard).

Additionally, it has also been found that the inventive coating compositions, at the inventive add-on amounts, etc., provide the same types of benefits with the aforementioned sewn, stitched, etc., side curtain airbags. Although such structures are

highly undesirable due to the high potential for leakage at these attachment seams, it has been found that the inventive coating provides a substantial reduction in permeability (to acceptable leak-down time levels, in fact) with correlative lower add-on amounts than with standard silicone and neoprene rubber coating formulations. Such add-on amounts will approach the 2.5 ounces per square yard, but lower amounts have proven effective (1.5 ounces per square yard, for example) depending on the utilization of a sufficiently high tensile strength and sufficiently stretchable elastomeric component within the coating composition on the target fabric surface. Again, with the ability to reduce the amount of coating materials (which are generally always quite expensive), while simultaneously providing a substantial reduction in permeability to the target airbag structure, as well as high resistance to humidity and extremely effective aging stability, the inventive coating composition, and the inventive coated airbag itself is clearly a vast improvement over the prior airbag coating art.

Surprisingly, the inventive coating may also be beneficially applied to a side curtain bag with less tight construction. Traditional woven side curtain bags utilize very tightly woven fabric to provide reduced seam combing possibilities and less stress on the applied coating. For example, a typical 420 denier Jacquard one-piece woven bag has a construction of 54 –57 yarns per inch. In comparison, a typical driver side and passenger side air bag fabric has a construction of 39 – 49 yarns per inch using the same 420 denier yarn. The inventive coating actually provides a very low permeability on a fabric using 420 denier yarn at construction less tight than 54 yarns per inch. The combination of this inventive high strength coating with lower construction results in faster weaving speed, lower fiber usage, more flexible fabric, better packing volume of

coated fabric, lower package weight and lower total cost. For fabric with lower construction, a higher strength material or higher coating weight may be necessary to achieve the required low overall permeability or characteristic leak-down time.

Of particular importance within this invention is the ability to pack the coated airbag cushions within cylindrical storage containers at the roof line of a target automobile in as small a volume as possible. In a rolled configuration (in order to best fit within the cylindrical container itself, and thus in order to best inflate upon a collision event downward to accord the passengers sufficient protection), the inventive airbag may be constructed to a cylindrical shape having a diameter of at most 23 millimeters with an unrolled fabric length of ~43 cm. In such an instance, with a 2 meter long cylindrical roofline storage container, the necessary volume of such a container would equal about 830 cm^3 (with the volume calculated as length[π]radius^2). Standard rolled packing diameters are at least 25 millimeters for commercially available side curtain airbag cushions (due to the thickness of the required coating to provide low permeability characteristics). Thus, the required cylindrical container volume would be at least 980 cm^3. Preferably, the rolled diameter of the inventive airbag cushion during storage is at most 20 millimeters (giving a packed volume of about 628 cm^3) which is clearly well below the standard packing volume. In relation, then, to the depth of the airbag cushion upon inflation (i.e., the length the airbag extends from the roofline down to its lowest point along the inside of the target automobile, such as at the windows), the quotient of the inventive airbag cushion's depth (which is standard at approximately 17 inches or 431.8 millimeters) to its rolled packed diameter should be at least about 18.8. Preferably this quotient should be about

21.6 (20 millimeter diameter), and, at its maximum, should be about 24 (with a minimum diameter of about 18 millimeters). Of course, this range of quotients does not require the depth to be at a standard of 17 inches, and is primarily a function of coating thickness, and thus add-on weight.

A further benefit derived from the utilization of the inventive side curtain airbag is the ability to utilize low pressure inflators therewith. In the past, the coatings applied (i.e., relatively thick, 4.0 ounces per square yard, for example, silicone-based formulations) provided effective sealing and thus sufficient gas retention for side curtain airbags, but only when the inflation pressure was extremely high. Since a high initial peak pressure introduced a large amount of inflation gas within the target airbag very quickly, an amount of time the target airbag remained inflated to a level which provided sufficient cushioning could be achieved. Unfortunately, although desired levels of inflation time and retained gas volume were met, these were basically very low and at the bare minimum on the scale of such desired characteristics. The inventive side curtain airbags provide definite improvements in gas retention and inflation times (i.e., characteristic leak-down times) over such traditionally silicone-coated airbags. The ultimate user may utilize much lower inflation pressures (i.e., 15-20 psi, and possibly lower) and still provide an inflated side curtain airbag which will remain sufficiently inflated to provide maximum cushioning benefits during long-duration rollover collisions. Such an ability to utilize a smaller inflator translates into better safety (lower the power output, the safer for the vehicle occupants upon inflation due to a lower likelihood to cause serious injury), less expensive inflators, lower volume inflators, and bags and fabrics which need to withstand lower physical demands upon

inflation.

While the invention will be described and disclosed in connection with certain preferred embodiments and practices, it is in no way intended to limit the invention to those specific embodiments, rather it is intended to cover equivalent structures structural equivalents and all alternative embodiments and modifications as may be defined by the scope of the appended claims and equivalence thereto.

Detailed Description and Preferred Embodiments of the Invention

Surprisingly, it has been discovered that any elastomer with a tensile strength of at least 1,500 psi and an elongation at break of at least 180% coated onto and over both sides of a side curtain airbag fabric surface at a weight of at most 2.5 ounces per square yard, and preferably between 0.8 and 2.0, more preferably from 0.8 to about 1.5, still more preferably from 0.8 to about 1.2, and most preferably about 0.8 ounces per square yard, provides a coated airbag cushion which passes both the long-term blocking test and long-term oven aging test with very low, and extended permeability upon and after inflation. This unexpectedly beneficial type and amount of coating thus provides an airbag cushion which will easily inflate after prolonged storage and will remain inflated for a sufficient amount of time to ensure an optimum level of safety within a restraint system. Furthermore, it goes without saying that the less coating composition required, the less expensive the final product. Additionally, the less coating composition required will translate into a decrease in the packaging volume of the airbag fabric within an airbag device. This benefit thus improves the packability for the airbag fabric.

The elastomer composition of this invention was preferably produced in accordance with the following Table:

TABLE 1

Standard Water-Borne Elastomer Composition

Component	Parts (per entire composition)
Resin (30-40% solids content in water)	100
Natrosol® 250 HHXR (thickener)	10
Irganox® 1010 (stabilizer)	0.5
DE-83 R (flame retardant)	10

(The particular resins are listed below in Table 2 and thus are merely added within this standard composition in the amount listed to form preferred embodiments of the inventive coating formulation).

The compounded composition's viscosity measured about 15,000 centipoise by a Brookfield viscometer. Once compounding was complete, the formulation was applied to both sides of a one-piece Jacquard woven airbag (having 420 denier nylon 6,6 yarns therein) as discussed within the Sollars, Jr. application noted above through a fixed gap procedure (with the gap between the coater and the bag surface at its greatest distance being approximately 100 microns). The bag was then dried at an elevated temperature (about 300°F for about 3 minutes) to cure and thus form to form the necessarily thin coating. As noted above, scrape coating may also be followed to provide the desired film coating; however, fixed gap coating provides the desired film width uniformity on the bag surface and thus is preferred. Scrape coating, in this sense, includes, and is not limited to, knife coating, in particular knife-over-gap table, floating knife, and knife-over-foam pad methods. The final dry weight of the coating is preferably from about 0.6-2.5 ounces per square yard or less and most preferably 0.8-

1.2 ounces per square yard or less. The resultant airbag cushion is substantially impermeable to air when measured according to ASTM Test D737, "Air Permeability of Textile Fabrics," standards.

TABLE 2

Standard Solvent-Borne Elastomer Composition

Component	Parts (per entire composition)
Resin (25-40% solids content in solvent)	100
Irganox® 1010 (stabilizer)	0.5
DE-83 R (flame retardant)	10

The resultant coatings were applied in the same manner as noted above for the water-borne elastomers.

In order to further describe the present invention the following non-limiting examples are set forth. These examples are provided for the sole purpose of illustrating some preferred embodiments of the invention and are not to be construed as limiting the scope of the invention in any manner. These examples involve the incorporation of the below-noted preferred elastomers within the coating formulations of TABLES 1 and 2, above.

Each coated bag was first subjected to quick inflation to a peak pressure of 30 Psi. Air leakage(SCFH) of the inflated bag was then measured at 10 Psi pressure. The characteristic leak-down time t(sec) was calculated based on the leakage rate and bag volume.

Example Number/ Elastomer	Tensile Strength (Psi)	Elongation at break (%)	t (sec). Before aging	T (sec.) Post-aging*	Coating add-on weight (oz/yd2)
1. Impranil 85 UD	6000	400	18.1	16.3	0.8
2. Ex 51-550	3100	320	110.2	105	0.8
3.Impranil ELH	7200	300	120.2	125	0.9
4. Ru 41-710	7000	600	27.3	26.4	0.8
5. Ru 40 –350	7000	500	34.4	36.2	0.8
6.Bayhydrol 123	6000	300	8.6	5.7	0.8
7.Dow Corning 3625***	700	90	< 2	< 2	2.1
8. Silastic 94-595-HC**	1400	580	< 2	< 2	1.8
9. Ru 40-415	5000	180	< 2	< 2	0.8
10.Sancure 861	3000	580	25.2	< 2	0.8
11. Witcobond 290H	6000	600	28.4	< 2	0.8

*: Aging conditions: 107 C oven aging for 16 days, followed by 83 C and 95% relative humidity aging for 16 days.
**: The resins are silicone rubbers.

As noted above, Examples 1-6 work extremely well and are thus within the scope of this invention. Examples 10 and 11 show some limitations, polyester based elastomers (Witcobond 290H) exhibit excellent heat aging (oxidation) stability but tend to hydrolyze easily at high humidity; polyether based elastomers (Sancure 861) have excellent hydrolysis resistance, but poor oxidation performance. However, these

elastomers have proven to be acceptable permeability reducers at higher add-on weights below the maximum of 2.5 ounces per square yard. Furthermore, although silicones show excellent resistance to heat aging and hydrolysis (humidity aging), they, however, possess limited tensile strength and tear resistance resistance. Natural rubber, SBR, chloroprene rubbers and others containing unsaturated carbon double bonds have excellent hydrolysis resistance. But the unsaturated carbon double bond that gives their elasticity oxidizes readily and the properties of the rubber change after heat aging. Elastomers that have good physical properties and excellent resistance to hydrolysis and oxidation are preferred for this application. Polyurethanes based on polycarbonate soft segments are the preferred materials for this application.

The airbag of Example 3 exhibited a sliding coefficient of friction constant of roughly 0.6. A comparative thick silicone-coated side curtain airbag which included a non-woven layer, exhibited a constant of about 0.8.

Description of the Drawings

FIG. 1 depicts the side, inside view of a vehicle prior to deployment of the inventive side curtain airbag.

FIG. 2 depicts the side, inside view of a vehicle after deployment of the inventive side curtain airbag.

FIG. 3 depicts a side view of a side curtain airbag.

FIG. 4 provides a side view of a side curtain airbag container.

FIG. 5 provides a cross-sectional perspective of the stored airbag within the container of

FIG. 4.

Detailed Description of the Drawings

As depicted in FIG. 1, an interior of a vehicle **10** prior to inflation of a side curtain airbag (not illustrated) is shown. The vehicle **10** includes a front seat **12** and a back seat **14**, a front side window **16** and a back-side window **18**, a roofline **20**, within which is stored a cylindrically shaped container **22** comprising the inventive side curtain airbag (not illustrated). Also present within the roofline **20** is an inflator assembly **24** which ignites and forces gas into the side curtain airbag (**26** of FIG. 2) upon a collision event.

FIG. 2 shows the inflated side curtain airbag **26**. As noted above, the airbag **26** is coated with at most 2.5 ounces per square of a coating formulation (not illustrated), preferably polyurethane polycarbonate. The inventive airbag **26** will remain sufficiently inflated for at least 5 seconds, and preferably more, as high as at least 20 seconds, most preferably.

FIG. 3 shows the side curtain airbag **26** prior to storage in its uninflated state within the roofline cylindrically shaped container **22**. The thickness of the airbag **26**, measured as the rolled packing diameter (as in FIG. 5, below) as compared with the depth of the airbag measured from the roofline cylindrically shaped container **22** to the bottom most point **28** of the airbag **26** either in its uninflated or inflated state will be at least 17 and at most 29, as noted above.

FIGs. 4 and 5 aid in understanding this concept through the viewing of the

rolled airbag **26** as stored within the container **22** along line **2**. The diameter measurement of the airbag **26** of Example 3, above, is roughly 20 millimeters. The standard depth of side curtain airbags is roughly 17 inches, or about 431.8 millimeters. Thus, the preferred packing volume factor is about 21.6. A comparative silicone-based thick coating add-on weight of about 4.0 ounces per square yard provided a diameter of about 25 millimeters for a factor of about 17.3.

There are, of course, many alternative embodiments and modifications of the present invention which are intended to be included within the spirit and scope of the following claims.